Advisory
Circular
U.S. Department of Transportation
Federal Aviation Administration

Subject: HALOCARBON CLEAN AGENT HAND FIRE EXTINGUISHERS FOR USE IN AIRCRAFT
Date: mm/dd/2005

AC No: 20-42XX
Initiated By:

X. Scope. This Advisory Circular (AC) contains minimum requirements for halocarbon clean agent hand fire extinguishers. Guidance for the use of Halon 1211, Halon 1301, water, dry powder, and Carbon Dioxide hand fire extinguishers can be found in AC No. 20-42C.

1. PURPOSE. This advisory circular provides methods acceptable to the Administrator for showing compliance with the hand fire extinguisher provisions in Parts **21,** 25, 29, 91, 121, 125, 127, and 135 of the Federal Aviation Regulations (FAR)for Halocarbon Clean Agents, and provides updated general information. In addition, the informationin this AC is considered acceptable for use by the owners/operators of small aircraft. This AC is also intended for use by those responsible for selecting, purchasing, installing, approving, and maintaining hand fire extinguishers and for those responsible for training personnel in their use. This AC does not constitute a regulation and is not intended to require anything beyond what is specifically required by the regulations.

2. FOCUS. Changes made to some of the requirements for hand fire extinguishers used in aircraft are of utmost concern to both aircraft owners operators and aviation maintenance agencies[1]. The Halon alternative halocarbon clean agents in this advisory circular were introduced in response to restrictions on the production of ozone-depleting halon fire extinguishing agents under the Clean Air Act Amendments of 1990 which implemented the Montreal Protocol signed September 16, 1987, as amended. This AC provides guidance for the safe use of halocarbon clean agent extinguishers. Nothing in this AC is intended to restrict new technologies or alternate arrangements provided that the level of safety prescribed by this AC is not lowered.

Any agent that is to be recognized by this AC or proposed for inclusion in this AC shall first be evaluated in a manner equivalent to the process used by the U.S. Environmental Protection Agency's Significant New Alternatives Policy (SNAP) program [2]. Agents covered by this circular have been revi[illegible]d and approved by the U.S. Environmental Protection Agency SNAP program for environmental and toxicological acceptability as halon replacements. The safe use guidance for Halocarbon clean agents (Halon alternatives)is based on an assessment of the relationship between Halocarbon agents in the blood and cardiac sensitization. This science-based approach has been adopted by the NFPA for total flood agents and has been published in the peer-reviewed literature and in NFPA 2001. The methodology used to assess the safe quantity

1 User Preference Survey http://www.fire.tc.faa.gov/ppt/systems/1
2 CFR Title 40: Protection of the Environment, Part 82-Protection of Stratospheric Ozone, Subpart G-Significant New Alternatives Policy Program and Subpart H-Halon Emissions Reduction

of agent in this document represents a change from the methodology previously used for Halon fire suppression agents.

The minimum safe volumes of spaces to be protected by Halocarbon extinguishers in this AC may be smaller than allowed by SNAP and Underwriters Lab (UL), Inc. and smaller than that allowed for clean halocarbon extinguishing systems in NFPA 2001 for Halocarbon Clean Agents. The reason for this additional safety factor is the inability for passengers to escape from an aircraft when airborne.

The designer should make every effort to consider the effects of ventilation, stratification and low oxygen hypoxia when sizing the necessary fire protection. This includes consideration of enhanced toxicity due to stratification into the cockpit for an aircraft in descent, as well as stratification of agent into lower level sleeping quarters while in-flight. Perfect mixing was assumed for the safe-use guidance in this AC.

3. NEW AC This advisory circular is intended to supplement AC 20-42C, Hand Fire-Extinguishers for use in Aircraft, dated, 3/7/1984 , which addresses Halon1211, Halon 1301, water, dry powder and Carbon Dioxide Hand Fire-Extinguishers.

4. RELATED FAR SECTIONS AND CODE OF FEDERAL REGULATIONS (CFR).

a. FAR 21.305.

b. FAR 23.561.

c. FAR 25.561; 25.851.

d. FAR 27.561.

e. FAR 29.561; 29.851; 29.853(e) and (f).

f. . *Could not find referenced section in FARs*

g. FAR 121.309(c).

h. FAR 125.119(b) and (c).

i. *Could not find referenced section in the FARs*

j. FAR 135.155.

k. CFR Title 46 and 49

l. CFR Title 40: Protection of the Environment, Part 82-Protection of Stratospheric Ozone, Subpart G-Significant New Alternatives Policy Program and Subpart H-Halon Emissions Reduction

RELATED ADVISORY CIRCULARS AND AIRWORTHINESS DIRECTIVES

a. AC 120-80 In-Flight Fires
b. AC 20-42C Hand Fire Extinguishers for Use in Aircraft
c. AD 93-07-15(2)(i) Airworthiness Directives; BOEING AND MCDONNELL DOUGLAS Models 707, 727, 737, 747, and 757 and McDonnell Douglas Models DC-8, DC-9, and DC-10 Series Airplanes

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DEFINITIONS.

a. Halon. A short derivation for "halogenated hydrocarbon" whose chemical structure is identified as a four digit number representing, respectively, the number of carbon, fluorine, chlorine, and bromine atom present in one molecule. Halon fire extinguishing agents approved for use include Halon 1211, Halon 1301, and a combination of the two (Halon 1211/1301). Both are liquified gases and typified as "clean agents," leaving no agent residue after discharge. Halons primarily extinguish fire by chemically interrupting the combustion chain reaction rather than by heat removal or physically smothering.

b. Halon 1211. The chemical name is bromochlorodifluoromethane, CBrC1F2. Halon 1211 is a multipurpose, Class A, B, C rated agent effective against flammable liquid fires. Due to its relatively high boiling point (-4° C/+25° F), Halon 1211 discharges as an 85 percent liquid stream offering a long agent throw range.

c. Halon 1301. The chemical name is bromotrifluoromethane, CBrF3. Halon 1301 is recognized as an agent having Class A, B, C capability in total flooding system; however, Halon 1301 offers limited Class A capability when used in portable fire extinguishers. The boiling point of Halon 1301 is -72° F (-6°C).

d. Hand Fire Extinguisher (Aircraft Hand Fire Extinguisher/Portable Fire Extinguisher). An approved, portable fire extinguisher as outlined in Section 6 of this AC, which can be used by aircraft occupants to combat accessible, incipient, on-board fires.

e. Halocarbon Clean Agents. Halocarbon Clean Agents that are currently commercialized include the hydrochlorofluorocarbons (HCFCs), perfluorocarbons (FCs or PFCs), hydrofluorocarbons (HFCs), fluoroiodocarbons (FICs), and fluoroketones (FKs). Halocarbon Clean Agents intended to replace Halon must meet acceptable global environmental guidelines, h[illegible] an acceptable toxicity and must be effective for the intended use. Halocarbon Clean Agents are electrically non-conducting, volatile, or gaseous fire extinguishants . As “clean agents”, they do not leave a residue upon evaporation. Halocarbon clean agents approved for use on aircraft include HCFC Blend B, HFC 227ea and HFC236fa. Halocarbon clean agents covered by this circular have been reviewed and approved by the U.S. Environmental Protection Agency SNAP program for environmental and toxicological acceptability as halon replacements.

f. HCFC Blend B._This extinguishing agent_is a blend comprised primarily of the chemical 1,1-dichloro-2,2,2-trifluoroethane, CF_3CHCl_2(HFC-123). Two inert gases are blended with the HCFC-123 to enhance flow distribution and fire extinguishing performance. The boiling point of the blend is 80.6°F (27°C). Due to this high boiling point, HCFC Blend B is discharged primarily as a liquid stream which then readily evaporates, offering a long agent throw range. HCFC Blend B is effective against Class A, B, and C fires. HCFC Blend B is distributed under the trade name Halotron I." The UL rated 5B:C HCFC Blend B extinguishers have passed the MPS.

__ HCFC Blend B is a multipurpose, Class A, B, C rated agent effective against flammable liquid fires. HCFC Blend B offers limited Class A capability when used in portable fire extinguishers. "Smaller extinguishers containing HCFC Blend B that are rated only for Class B and Class C fires will still be effective on smaller Class A fires. To achieve the minimum 1A rating, one of the multiple tests required is the extinguishment of an eight feet wide by eight feet tall wood panel. While smaller extinguishers do not contain a sufficient amount of agent to extinguish this size of fire, they have been shown to be effective against Class A fires, such as seat fires, onboard aircraft. HCFC Blend B extinguishers rated for a 1A fire contain 11.0 Lb. of agent."

(This is an expanded version of NFPA 10, Section 5.2.1.1, which states "Certain smaller fire extinguishers that are charged with a multipurpose dry chemical or a halogenated agent are rated on Class B and Class C fires, but have insufficient effectiveness to earn the minimum 1-A rating even though they have value in extinguishing smaller Class A fires.)

g. HFC 227ea . This extinguishing agents comprised of the chemical 1,1,12,3,3-heptafluoropropane CF3CHFCF3 (HFC-227ea). The boiling point of the agent is 1.9°F (-16.4°C). Due to this boiling point, HFC-227ea is discharged as a mixed liquid and vapor stream which readily evaporates. HFC-227ea is effective against Class A, B, and C fires. HFC-227ea is distributed under the trade name FM-200. The UL rated 5B:C HFC-227ea extinguishers have passed the MPS. HFC-227ea extinguishers rated for a 1A fire contain _11_ lbs. of agent.

h. HFC-236fa. The chemical name is Hexafluoropropane ($CF_3CH_2CF_3$). HFC-236fa is a multipurpose, Class A, B, C rated agent effective against flammable liquid fires. Due to its relatively high boiling point (-1.4° C/+29.5° F), HFC-236fa discharges predominately as a liquid stream offering a long agent throw range. See appendix 2. HFC-227ea offers limited Class A capability when used in portable fire extinguishers. Smaller extinguishers containing HFC-236fa that are rated only for Class B and Class C fires will still be effective on smaller Class A fires. To achieve the minimum 1A rating, one of the multiple tests required is the extinguishment of an eight feet wide by eight feet tall wood panel. While smaller extinguishers do not contain a sufficient amount of agent to extinguish this size of fire, they have been shown to be effective against Class A fires, such as seat fires, onboard aircraft. HFC-236fa extinguishers rated for a 1A fire contain 9.5 lbs. of agent.

(Agent manufacturer will provide information)

i. Lowest Observable Adverse Effect Level (LOAEL). The lowest concentration at which an adverse toxicological or cardiac sensitization event has been observed.

j. No Observed Adverse Effect Level (NOAEL). The highest concentration at which no adverse toxicological or cardiac sensitization event has been observed.

6. APPROVED HAND FIRE FXTINGUISHERS. Hand fire extinguishers are acceptable under FAR Sections 25.851(a)(1), 29.851(a)(1), 121.3 09(c), 127.107(c) and 135.155 if they have been approved in accordance with FAR 21, Section 21.305. In accordance with Section 21.305 (d) of the FAR the Federal Aviation

Administration (FAA) accepts hand fire extinguishers approved in a manner equivalent to Underwriters'Laboratories, Inc. (UL), Factory Mutual Research Corp., or approved by the U.S. Coast
Guard under Title 49 of the CFR for use in aircraft. In accordance with Far 21, Section 21.305, FAA advisory circulars are one means for approval of hand fire extinguishers.
(Hand extinguishers approved by UL and the other allowed approval labs need to be used in larger spaces, to be considered safe in the closed confines of aircraft spaces, where there is no means of egress. The smallest allowable protected space in aircraft, described in this AC, is in most cases larger than what these approval labs will allow)

Although Parts 91 and 125
do not require FAA approval of hand fire extinguishers, the information in this AC is considered acceptable for use by Parts 91 and 125 operators. Any agent that is to be recognized by this AC or proposed for inclusion in this AC shall first be evaluated in a manner equivalent to to the process used by the U.S. Environmental Protection Agency's Significant New Alternatives Policy (SNAP) program in accordance with the CFR Title 40, Part 82, Subpart G. Halocarbon Clean Agent extinguishers intended to replace Halon 1211 5B:C size extinguishers onboard transport category aircraft should pass the Hidden Fire Test and The Seat Fire/Toxicity Test identified in DOT/FAA/AR-01/37 Development of a Minimum Performance Standard (MPS) for Hand-Held Fire Extinguishers as a replacement for Halon 1211 on Civilian Transport Category Aircraft. A Permanent label must be affixed to the extinguisher identifying FAA approval for use on board commercial aircraft. Operators of non-transport category aircraft should become familiar with the information in this AC and the precautions listed in paragraph 8f for the different types of fire extinguishers. In addition, the recommendations of the extinguishermanufacturer should he considered.

7. DISCUSSION.

a. Types of Fires. To properly select an appropriate extinguisher for use in an aircraft, it is recommended that consideration be given to the following classes of fires (as defined in the National Fire Protection Association (NFPA) Standard 10) that are likely to occur:

(1) Class A. Fires involving ordinary combustible materials, such as wood, cloth, paper, rubber, and plastics for which the quenching and cooling effects of quantities of water, or of solutions containing a large percentage of water, are of prime importance.

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(2) Class B. Fires involving flammable liquids, oils, greases, tars, oil
base paints, lacquers, and flammable gases for which extinguishing agents such as CO_2 are essential.

(3) Class C. Fires which involve energized electrical equipment and where the electrical nonconductivity of the, extinguishing media is of importance.

(4) Class D. Fires which involve combustible metals, such as magnesium, titanium, zirconium, sodium, lithium, and potassium, and require extinguishing agents of the, dry powder types. The recommendations of the

manufacturer for use of those extinguishers should he followed because of the possible chemical reaction between the burning metal and the extinguishing agent.

b. Extinguishing Agents Appropriate for Types of Fires. The following extinguishing agents are recommended, as appropriate, for use on the types of fires specified below and as defined in paragraph 7a of this AC:

(1) Carbon Dioxide - Class B or C.

(2) Water - Class A.

(3) Dry Chemicals - Class A, B, or C.

(4) Halons- Class A, B, or C.

(5) Halocarbon Clean Agents - Class A, B, or C.

(6) Specialized Dry Powder - Class D.

NOTE: Only "all purpose" or A, B, C dry chemical powder extinguishers containing monoammonium phosphate have a UL Class A, B, C rating; all other powders have a Class B, C rating only. It should also be noted that various dry chemical agents are corrosive to sensitive electrical components and equipment. For example if monoammonium phosphate is ever used to suppress a fire in close proximity of flight critical equipment, the equipment should be inspected for signs of contamination and thoroughly cleaned and tested prior to re-entry into service.
(See reference to NFPA 410 below.)

NFPA 410 Aircraft Maintenance (Addendum) A-7-3.1
All-purpose (ABC) dry chemical-type extinguishers should not be used in situations where aluminum corrosion is a problem.

NFPA Fire Protection Handbook Chapter - Basics of Fire and Science

Extinguishment with Dry Chemical Agents
One reason that dry chemical agents other than monoammonium phosphate are popular has to do with corrosion. Any chemical powder can produce some degree of corrosion or other damage, but monoammonium phosphate is acidic and corrodes more readily than other dry chemicals, which are neutral or mildly alkaline. Furthermore, corrosion by other dry chemicals is stopped by moderately dry atmosphere, while phosphoric acid has such a strong affinity for water that an exceedingly dry atmosphere would be needed to stop corrosion.

Although a bit dated, we have extracted parts of an article published in the Nov. / Dec. 1983 issue of "Air Transport Newsletter" written by Ronald Horn, then Manager/Ground Safety for Eastern Airlines and titled "Class A-B-C Extinguishers Damage Aircraft".

"The A-B-C extinguishers have excellent fire-fighting capability, but the mono-ammonium-phosphate chemical agent melts and flows when it comes into contact with heat. This is how it gets its Class A rating. This chemical is highly corrosive to aluminum and once it contacts hot aluminum and flows down into the structural cracks and crevices it cannot be washed out as the B-C dry chemical agents can.

Once an A-B-C extinguisher is used on an airplane, it is necessary to disassemble the aircraft piece by piece and rivet by rivet to accomplish cleanup. Failure to do so will result in destruction of the aircraft by corrsion."

TO SUM UP: ABC EXTINGUISHERS (HAND PORTABLE AND WHEELED) ARE NOT PROPER AIRCRAFT (FIXED WING OR ROTARY) FIRE PROTECTION, ONBOARD, ON RAMPS OR IN HANGERS.

c. Numeral Ratings. Numerals are used with the identifying letters for extinguishers labeled for Class A and Class B fires. The "numeral" indicates the relative extinguishing effectiveness of the device on a given size fire

which is dependent on the agent, the capacity of the device, discharge times, and design features. For example, an extinguisher rated as 4A should extinguish about twice as much Class A fire as a 2A rated extinguisher. A 2 1/2-gallon water extinguisher is rated 2A. On an extinguisher rated for Class B fires, the numeral rating precedes the letter "B". Numeral ratings are not used for extinguishers labeled for Class C or D fires. Extinguishers that are effective on more than one class of fires have multiple "numeral-letter" and "letter" classifications and ratings; for example, 5B:C.

d. Halocarbon Agents. For hand fire extinguishers employing halocarbon clean agents, the following ASTM Specifications cover the requirements Apply:

(1) HCFC Blend B should meet the requirements of ASTM Specification ASTM D7122. *(The standard has passed the ballot vote and there is an ASTM meeting on June 15th, 2005 in which the standard process will be finished. It will probably be somewhere in July that the standard becomes available on the ASTM website).*

(2) HFC 227ea should meet the requirements of ASTM Specification D6064

(3) HFC 236fa should meet the requirements of ASTM Specification D6541.

e. Halocarbon Clean Agent Extinguishers.

(1) For occupied spaces on transport category aircraft, extinguishers employing halocarbon clean agents should have a minimum UL 5B:C ratings, and not less than 8 seconds effective discharge time, and not less than an 8-foot (3 m) throw range. Longer throw ranges provide a significant advantage in fighting fires in larger transport category aircraft.Halocarbon Clean Agent extinguishers with a minimum UL 5B:C rating, intended to replace halons in transport category aircraft should contain the following statement on the label, “FAA Approved. Meets the minimum performance standards for handheld extinguishers as defined by DOT/FAA/AR-01/37.”
The minimum performance standard sets the requirements for the extinguishment of hidden fires and seat fires. It also sets the toxicity requirements for agent decomposition products. Agent toxicity guidance is provided in this advisory circular.

(2) For accessible cargo compartments, in combination passenger/cargo and cargo aircraft, halocarbon clean agent extinguishers the amount of extinguishing agent required for this application will be outside the range of allowable exposures, and protective breathing equipment should be donned before entering the compartment. *FAR 25.857 requires that the aircraft systems are designed such that unsafe concentrations of extinguishing agent, for fighting accessible cargo compartment fires, will not enter the cabin.*

(3) For accessible cargo compartments smaller than 200 cubic feet, which are not protected by fire protection flooding systems, in combination passenger/cargo and cargo aircraft, halocarbon clean agent extinguishers should have a listed classification not less than 2-A:10B:C.

(4)For accessible cargo compartments of 200 cubic feet and larger, which are not provided with fire suppression flooding systems, in combination passenger/cargo and cargo aircraft, a minimum of 3 portable fire extinguisher bottles of halocarbon clean agent with a minimum UL rating of 4A: 20B:C should be readily available . Provide a minimum of 30 minutes of protective breathing, which must meet the requirements of Technical Standard Order (TSO) C-116, Action Notice 8150.2A, or equivalent. This protective breathing equipment must be stored adjacent to the cargo compartment entrance.

Task Group Note: The Halocarbon Extinguishers probably can not attain a 4A:80B:C Rating for a handheld extinguisher. A 4A:20B:C rating is sufficient for fires likely to occur. This is in conflict with the A/D 93-07-15.

Currently Available extinguishers: Note that the halon replacements have relatively poor UL class B:C performance relative to Halon 1211. Halocarbon clean agent extinguishers are not yet available in 4A UL ratings.:

Halon 1211	***UL 2A-40B:C*** ***UL 4A:80B:C***	***13 lb*** ***17 lb***
HFC236f	***UL 2A-10B:C***	***13.25 lb***
HCFC Blend B	***UL 2A 10B:C***	***15.5 lb***
HFC 237ea		

Task Group: Note that Airworthiness Directive #AD 93-07-15 requires (for particular aircraft- with options) a minimum of 48 pounds of Halon 1211 or it's equivalent installed in portable bottles for the purpose of fighting a fire in class B cargo compartment of 200 cubic feet or larger. This AD also requires a minimum of 30 minutes of protective breathing RJM

Wording from this AD: " At least two bottles of Halon 1211 must be a minimum of 16 lb. capacity." Note options!

(4) Extinguishers (mounted alongside the entrance to the cargo compartment) intended for use to fight cargo fires in combination passenger/cargo and cargo aircraft, should be available to extinguish cabin fires. Select an extinguisher for that cargo compartment that meets the safe use guidance for the aircraft cabin. It should not exceed the maximum safe weight for the aircraft cabin.

If no extinguisher, intended for use to fight cargo fires, is available that meets the safe use criteria for the aircraft cabin, consider installing a clean agent fire suppression system in that cargo compartment.

If no extinguisher, intended for use to fight cargo fires, is available that meets the safe use criteria for the aircraft cabin,
do not use an extinguisher with a lower UL Rating than recommended for the cargo compartment. Select the safest extinguisher of the required rating (the extinguisher that can be used safely in the smallest space).

If the contents of the extinguisher exceed the safe levels for the cabin, place a warning on or alongside the bottle stating: "Discharge of the entire

contents of this size bottle into the occupied cabin area exceeds safe exposure limits. Use only the amount necessary to extinguish a fire."

(5) If halocarbon clean agent extinguishers are installed in a nonventilated passenger or crew compartment, and the compartment cannot be vented, and the occupants cannot leave if the extinguishers are discharged, then the total agent available ***from all the extinguishers*** should not be capable of producing concentrations in the compartment, by volume at 70 Deg F (21 Deg C), assuming perfect mixing, that exceeds the agent's safe exposure guideline as indicated by its PBPK derived 5 minute safe human exposure concentration, if known (Table 1). Otherwise, If PBPK data is not available, the Agent No Observable Adverse Effect Level (NOAEL) is to be used (Tale 2). Exposures of Concentrations up to the No Observable Adverse Effect Level (NOAEL) value must be limited to less than 5 minutes. See the Precautions Section for clarity.

Table 1. Maximum Safe Exposure Concentrations for unventilated Compartments

Agent	Maximum Safe 5 minute Human Exposure[a,b,c] (%v/v)	NOAEL[b,c,d] (%v/v)	FAA Guidelines: Safe Concentration (%v/v)
HCFC Blend B	unknown	1.0[e]	1.0[f]
HFC 227ea	10.5	9.0	10.5[f,g]
HFC236fa	12.5	10.0	12.5[f,g]
Halon 1211[h]	1.0	0.5	h
Halon 1301[h]	6.0	7.5	h

Notes:

a) Data derived from the EPA-approved and peer reviewed PBPK model or it's equivalent found in:

b) Vinegar, A., Jepson, G.W., Cisneros, M., Rubenstein, R. and Brock, W.J. (2000): Setting Safe Acute Exposure Limits for Halon Replacement Chemicals Using Physiologically Based Pharmacokinetic Modeling, Inhalation Toxicology, 12:751-763.Based on constant exposure level for duration of exposure.

(c)NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems, 2004 Edition, National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts, Feb. 2004.

(d) Based on Canine Data

(e) Obtained from the manufacturer

(f) Immediate descent to 8,000 feet or lower is recommended for all aircraft to minimize exposure to halogenated gases.

(g) Unpressurized aircraft should descend at a minimum rate of 1,000 ft/minute if agent weights are greater than half the maximum safe weight for a given volume to avoid the life-threatening hazards of low- oxygen hypoxia resulting from the agent displacing oxygen from the air in the compartment.

(h) Halon Data is provided for comparison only. See AC20-42C for current Halon Guidance.

$$\left(\frac{W}{V}\right)_{Safe} = \left(\frac{1}{S \bullet A}\right) \bullet \frac{(C_{Safe})}{(100 - C_{Safe})}$$ where A= Altitude correction factor for S

For pressurized aircraft, use the pressure altitude of 8,000 feet: A=1.346
For unpressurized aircraft, use the pressure altitude of 14,000 feet: A=1.702

V is the net volume of the space, calculated as the gross volume minus the volume of fixed structures, ft^3.

W is the maximum safe weight of the clean agent, lb for a volume V, **(if all extinguishers are dicharged)**;

S is the specific volume of the agent at 70° F (21° C), ft^3/lb;
C_{Safe} is the FAA allowed clean agent concentration (% by volume

$X_{1\ Bottle}$ is the minimum safe compartment volume for 1 bottle

The minimum safe compartment volume is based on all bottles in the aircraft cabin:

$$X_{All\_Bottles} = X_{1Bottle} \bullet \#Bottles$$

Table 2. Specific Volume of halocarbon agents

Agent	Specific Volume of Agent at 1 atm and 70deg F (ft3/lb)
HCFC Blend B	2.597[a]
HFC 227ea	2.2075[a,b]
HFC-236fa	2.4574[a]

a) Obtained from the manufacturer.

b) NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems, 2004 Edition, National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts, Feb. 2004.

This calculation includes an allowance for the normal leakage from a "tight" enclosure due to agent expansion.

This maximum safe weight for nonventilated aircraft is to be used for poorly ventilated compartments, and when graphs for ventilated aircraft are not available for a particular agent.

If extinguishers exceeding the maximum safe weights, are installed, use of protective breathing equipment is recommended.

The toxicity guidelines in the proposed halocarbon advisory circular allow the following minimum compartment volumes for the following 5 B:C extinguishers, released at 70°F: (21.1°C)

Table 3. Agent Toxicity: Minimum Safe Volume for 1 extinguisher, $X_{1Bottle}$[a] (No Ventilation, 70 F)

Agent	Notes	Agent Weight (lbs)	Minimum Safe Volume for 1 extinguisher, $X_{1Bottle}$[a] (ft^3)		
			For Sea Level (For info only)	For 8,000 ft P Altitude (Pressurized A/C)	For 14,000 ft P Altitude (NonPressurized A/C)
Halotron I HFC236fa	b	5.0 4.75	1286 85	1730 110	2188 139

HFC227ea		5.75	108	146	184
Halon 1211	b, c	2.5	556	749	947
Halon 1301	b, c	5.0	243	327	414

a) Multiply this number by the number of extinguishers in the aircraft to obtain the minimum safe volume.
b) Do not use in small spaces.
c) If the proposed halocarbon extinguisher AC was applied to the Halons. This data is provided for comparison purposes.

(6) For ventilated compartments, the graphs shown in appendix 1 of this AC can be used to find safe extinguisher sizes and necessary descent rates, when compartment volume and ventilation rates are known. These graphs are based on the assumption of perfect mixing. The weight to be used is based on all extinguishers on-board the aircraft. These graphs are essentially for aircraft for which ventilation rates are controllable and known.

Unpressurized Aircraft (ventilated compartments) should descend at a minimum rate of 1,000 ft/minute if agent weights are greater than half the maximum safe weight for a given volume to avoid the life threatening hazards of low oxygen hypoxia resulting from the agent displacing oxygen from the air in the compartment. This guidance should be followed regardless of ventilation rate.

Immediate descent to 8,000 feet or lower is recommended for all unpressurized aircraft to minimize exposure to halogenated agents.

If extinguishers exceeding the maximum safe weights, are installed, use of protective breathing equipment is recommended.

(7) Halocarbon clean agents have their greatest effectiveness on Class B and C fires. Extinguishers with greater capacity are also rated for Class A fires. Extinguishers which are not rated for use on Class A fires, have been shown to be effective in extinguishing surface Class A fires such as aircraft seat fires and wire bundle fires. (Detailed information on agent characteristics, concentration requirements, health hazards, and extinguishing limitations may be obtained by consulting the agent manufacturer.

(8) For access to underseat, overhead, and other difficult to reach locations, it is recommended that extinguishers be equipped with a discharge hose or adjustable wand. An extinguisher with a discharge hose or adjustable wand is more likely to result in the extinguisher being properly held in an upright position during use and provides a means of directing a stream of agent to more inaccessible areas.

(9) Health and safety advantages associated with small volume occupied spaces on larger aircraft (flight decks) do not usually exist for the smaller aircraft. These advantages are a forced ventilation system, availability of oxygen masks, and availability of a second individual capable of flying the aircraft.

(10) Refer to the Precautions section 7(e)9 for actions that personnel should take to limit exposure.

g. Location and Mounting of Hand Fire Extinguishers in Passenger Compartments. It is acceptable to install fire extinguishers in passenger

compartments according to the following criteria:

(1) In general, locate hand fire extinguishers adjacent to the hazardous area (i.e., galleys, accessible baggage or cargo compartments, electrical equipment racks, etc.) they are intended to protect.

(2) If no clearly defined hazardous area exists, locate the hand fire extinguishers as follows:

(a) When one extinguisher is used, locate it at the flight attendant's station or, when no flight attendant is required, locate the extinguisher at the passenger entrance door.

(b) When two or more extinguishers are used, locate one at each end of the passenger compartment and space the remainder uniformly within the cabin area.

(3) Mount hand fire extinguishers so that they are readily available. If they are not visible in their mounted position, a placard (with letters at least 3/8-inch high) may be used to indicate their location.

(a) Due to the weight of hand fire extinguishers, the aircraft structure and extinguisher mounting brackets should be capable of withstanding the inertia forces required in Sections 23.561, 25.561, 27.561, and 29.561 of the Federal Aviation Regulations, with the hand fire extinguisher installed. If extinguishers are replacing halons, the mounting system may need to be strengthened to meet these guidelines, as the halocarbon clean agent extinguishers may be much heavier than the halons.

(b) The weight of the hand fire extinguisher and its mounting bracket should be added to the aircraft empty weight and a new empty weight center of gravity computed.

(c) Halocarbon clean agent extinguishers can be twice the weight of the Halon extinguishers they are replacing. Mount them in a low enough position that a frail, short flight attendant can access them quickly. INSERT NEW (c)Currently FAA approved 5B:C Halon replacement fire extinguishers weigh over 9 pounds. Installation of an extinguisher should include vertical reach combined with horizontal (offset) reach to ensure ease of retrieval from overhead compartments. The vertical reach should not exceed 74.5 in. (189.23 cm) combined with an offset reach of 7.87 in. (20cm) to permit a 5 percentile female, 60.5 in. (153.67 cm.) tall to quickly access the extinguisher.

(4) Fire extinguisher selection should be made with regard to the type of fire hazard (Class A, B, C, or D) to he encountered. If extinguishers intended for different classes of fire are grouped together, their intended use should be marked conspicuously to aid in the choice of the proper extinguisher at the time of the fire.

h. Location and Mounting of Hand Fire Extinguishers in Small Single

Engine and Multiengine Aircraft.

(1) Locate hand fire extinguishers so that they am easily accessible to the flight crew and the passengers.

(2) Hand fire extinguishers should not he allowed to lie loose on shelves or seats. Fire extinguishers and mounting brackets should be properly mounted to the airframe structure capable of withstanding the inertia forces required by the FAR sections listed in paragraph 7g(3)(a) of this AC.

8. GENERAL INFORMATION.

a. Extinguishing Agent Toxicity. Since the toxicity groupings of various fire extinguishing agents are no longer considered valid comparisons, the Underwriters' Laboratories, Inc., classification of comparative life hazards of various chemicals has been eliminated.

b. Corrosion by Extinguishing Agents. Carbon dioxide is not corrosive and will have no damaging effect other than cold shock effect on ceramic electronic components. Water itself is not corrosive, but may be rendered corrosive by the addition of antifreeze solutions. Various dry chemical agents are corrosive to most sensitive electronic components and instruments. Neat halocarbon clean agents are not corrosive, but any replacement agent's corrosive properties should be reviewed for acceptability to aircraft materials.

c. Operating Temperature Requirements for Halocarbon Clean Agent Hand Fire Extinguishers.UL 2129 provides that “Not less than 90 percent(by weight) of the rated capacity of halocarbon clean agent fire extinguishers shall be discharged when an extinguisher is operated after being conditioned at the minimum storage temperature (minus 40+/- 4°F (minus 40+/- 2°C), or minus 65+/-4°F (minus 54.5+/- 2°C) as applicable, and at 120+/- 4°F (48.9+/- 2°C)for at least 16 hours. There shall be no leakage from the extinguisher during the conditioning cycle”

d. Factory Sealed ("Disposable Type") Fire Extinguishers. Disposable type fire extinguishers should be maintained and inspected in accordan with the nameplate instructions.

(1) Nonrefillable disposable fire extinguishers have plastic discharge heads installed. Care should he exercised in the location of this type of fire extinguisher to eliminate damage.

(2) Nonrefillable disposable fire extinguishers are exempt from the periodic hydrostatic test requirements.

e. Properties of Halogenated Agent Extinguishers.

(1) Halocarbon clean agents are similar to the halons in that they are suitable for use in cold weather and leave no residue.

(2) Halotron 1, HFC 236fa, and HFC 227ea are approximately half as effective as Halon 1211 for a given weight of agent.

(3) HCFC Blend B is a rapidly evaporating liquid. HFC227ea andHFC-236fa are liquefied gases. These agents are pressurized with inert gases. The halocarbon agent leaves the nozzle in a stream that is partly liquid and partly gas.

(4) Halocarbons that are gaseous upon discharge have a more limited throw range. Halocarbons have discharge characteristics dependent on the halocarbon and the nozzle design. Throw ranges of 10 feet and higher provide significant advantages in fighting fires in large aircraft cabins.

(5) Because they are discharged as a gas or rapidly evaporating liquid, halocarbon clean agents leave no chemical residue behind to contaminate or corrode aircraft parts or surfaces.

(6) Other advantages of halocarbon clean agents are lower cold shock characteristics on electronic equipment, no degradation of visual acuity, and lower pressure.

f. Precautions.

(1) **Extinguish the fire immediately. Fires can grow exponentially with time.** ***Highlight and Bold this text.***

(2) Do not substitute two 2B:C extinguishers for one 5B:C extinguisher. The fire can grow quickly prior to the discharge of the second extinguisher.

(3)Exposure to halocarbon clean agents at the allowed concentrations and durations is of far less concern than exposure to combustion gases produced by burning aircraft materials and the thermal decomposition products of the halocarbon clean agent. Decomposition products from the burning materials, especially carbon monoxide, smoke, heat, and oxygen depletion, may create an immediate toxic hazard.

4) Exposure to high levels of Clean Halocarbon vapors exceeding the amounts allowed in this AC may result in dizziness, impaired coordination, reduced mental sharpness, and heart arrhythmias depending on agent concentrations and durations. See "NFPA Standard 2001 for Clean Agent Fire Extinguishing Systems" for more detailed information.

(5) **For compartments that are smaller than the minimum safe volume for a 5B:C extinguisher, the safest extinguisher should be placed in the aircraft. Place warning label on the extinguisher to stop discharge as soon as the fire is extinguished.**

Highlight and Bold this text. Also, how else can we inform the user of this?

(6) Unnecessary exposure of personnel to halocarbon clean agent including at or below the No Observable Adverse Effect Level, NOAEL, and halon decomposition products shall be avoided. Means shall be provided to limit exposure to no longer than 5 minutes. After extinguishing the fire, the aircraft should be ventilated at the highest possible rate to rid the cabin and cockpit of hazardous gases and smoke. Small unpressurized aircraft/ rotorcraft can increase ventilation significantly by opening windows and dropping to an altitude of 8,000 feet or lower. Protective

breathing equipment should be used if available. Unprotected personnel should not enter a protected space during or after agent discharge, until ventilated. Exposures to halocarbon clean agents longer than 5 minutes may have anesthetic and/or developmental effects.

(7) The decomposition products of the halocarbon clean agents have a characteristic sharp, acrid odor, and an eye Irritating effects, even in concentrations of only a few parts per million. Halogenated agents decompose when subjected to flame or hot surfaces at approximately 900 Deg F (482 Deg C).

(8) Never discharge halocarbon Clean Agents or water on Class D (burning metal) fires. These agents may react vigorously with the burning metal.

(9) For nonventilated conditions use the “Maximum Safe 5 minute Human Exposure concentrations” in table 1 to find safe extinguisher sizes. NOAELS from table 2 can be used if no data is listed in table 1.

(10) For ventilated compartments, the graphs shown in appendix 1 in this AC can be used to find safe extinguisher sizes when compartment volume and ventilation rates are known. These graphs are derived from Physiologially- Based Pharmacokinetic (PBPK) modeling of concentration-time agent decay curves for air exchange rates ranging from 1 to 6 air exchanges per minute.

(11) If graphs are not provided for an agent in this AC, use the Maximum Safe 5 minute Human Exposure concentrations in table 1 to find safe extinguisher sizes. NOAELS from table 2 can be used if no data is listed in table 1.

The AC can be updated as new agents and new graphs are submitted to the FAA Transport Aviation Directorate.

g. Helpful Hints.

(1) Best results in fire fighting are generally obtained by attacking the base of the fire at the near edge of the, fire and progressing toward the back of the fire by -moving the fire extinguisher nozzle rapidly with a side-to-side sweeping motion.

(2) The effective discharge time of a 2B or 5B rated extinguisher is approximately 8-to-10 seconds. Due to this relatively short effective time span, proper training and use of the fire extinguisher are important.

(3) Care must be taken not to direct the initial discharge at the burning surface at close range (less than 5-to-8 feet) because the high velocity stream may cause splashing and/or scattering of the burning material.

(4) Ventilate the compartment promptly, overboard, if possible, after successfully extinguishing the fire to reduce the gaseous combustion and gases produced by thermal decomposition. Follow fire fighting procedures for protective breathing apparatus.

h. Inspection, Hydrostatic Test and Life Limits. Recommended procedures for the inspection, hydrostatic test and life limits of pressure cylinders are outlined in Part 173, Chapter 1, Subparts B, and G of CFR 49 currently in effect. See CFR 49, Part 173.306(c) (5) regarding retest intervals for fire extinguishers.

9. RELATED RESEARCH MATERIAL

- In-Flight Aircraft Seat Fire Extinguishing Tests(Cabin Hazard Measurements), DOT/FAA/CT-82/111, Hill, R.G., and Speitel, L., December 1982
- Halon Extinguishment of Small Aircraft Instrument Panel Fires, DOT/FAA/CT-86/26, Slusher, G.R., Wright, J.A., and Speitel, L.C., December 1986
- NFPA 408, Standard for Aircraft Hand Portable Fire Extinguishers, 1999 Edition
- NFPA 12B Standard on Halon 1211 Fire Extinguishing Systems, 1990 Edition
- NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems, 2004 Edition, National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts, Feb. 2004.
- Vinegar, A., Jepson, G.W. and Overton, J.H (1998): PBPK Modeling of Short-term (0-5 min) Human Inhalation Exposures to Halogenated Hydrocarbons, Inhalation Toxicology, 10:411-429.

  Note: This is an early document, which provides human validation data for the PBPK approach and provides detailed mathematical descriptions of the respiratory component of the PBPK model. This document also has an example of Halon 1211 release in a military tank and the evaluation of the exposure and consequences using PBPK modeling.

- Vinegar, A., Jepson, G.W., Cisneros, M., Rubenstein, R. and Brock, W.J. (2000): Setting Safe Acute Exposure Limits for Halon Replacement Chemicals Using Physiologically Based Pharmacokinetic Modeling, Inhalation Toxicology, 12:751-763.

  Note: This is the document that provides the basis for the tables in NFPA 2001 (2000 edition). It also provides safe exposure data for Halon 1301, which is not shown in NFPA 2001. It is interesting to note using the PBPK modeling approach, Halon 1301 cannot be safely used at concentrations above 6% v/v for more than 5 minutes.

- Vinegar, A (2001): Modeling Cardiac Sensitization Potential of Humans Exposed to Halon 1301 or Halon 1211 Aboard Aircraft, Aviation, Space and Environmental Medicine, Vol 72, No. 10.

  Note: This paper illustrates Halon 1301 and Halon 1211 application aboard aircraft and compares the predicted human blood levels to cardiac sensitization. While predicted Halon 1301 blood levels did not exceed cardiac sensitization thresholds, Halon 1211 levels did exceed the thresholds in several areas.

- Vinegar, A., Jepson, G.W., Hammann, S.J., Harper, G., Dierdorf, D.S. and Overton, J.H.(1999): Simulated Blood Levels of CF_3I in Personnel Exposed During Its Release from an F-15 Jet Engine Nacelle and During Intentional Inhalation, AIHA Journal, 60:403-408.

  Note: This paper establishes the precedent of predicting human blood levels of agent during conditions of changing exposure concentration. This sort of an approach would be required to accommodate perfect mixing decay curves for various air change rates

- Webster, Harry, "Development of a Minimum Performance Standard (MPS) for Hand-Held Fire Extinguishers as a replacement for Halon 1211 on Civilian Transport Category Aircraft" Federal Aviation Administration Report No.DOT/FAA/AR-01/37, 2002

- Eklund, Thor I. "Analysis of Dissipation of Gaseous Extinguishing Agents in Ventilated Compartments"
  Federal Aviation Administration Report No. DOT/FAA/CT-83/1, 1993.

  Note: This report develops the calculation of agent dissipation as a function of time using the perfect stirrer model. It also describes the theory and assumptions used in the development of the nomographs for the Halons.

- Speitel, Louise C. "Setting Safe Acute Exposure Limits for Dissipating Gaseous Halon and Halocarbon Extinguishing Agents in Ventilated Compartments" Federal Aviation Administration: Report to be published.
  Note: This report provides a simple first order pharmacokinetic solution for changing concentrations of halocarbons.

- Slusher, Gerald R., Wright, Joseph, Demaree, James, "Halon Extinguisher Agent Behavior in a Ventilated Small Aircraft", Federal Aviation Administration Report No. DOT/FAA/CT-86/5, 1986

- Slusher, G.R., Wright, J., Demaree, J.E., Neese, W.E. "Extinguisher Agent Behavior in a Vantilated Small Aircraft, Federal Aviation Administration Report No. DOT/FAA/CT-83-30,1984

- Abramowitz, A., Neese, W., Slusher, G, "Smoke and Extinguisher Agent Dissipation in a Small Pressurized Fuselage" Federal Aviation Administration, Report No. DOT/FAA/CT-89/31, 1990.

- Krasner, L.M. "Study of Hand-held Fire Extinguishers aboard Civil Aviation Aircraft" Factory Mutual Research Corporation, Federal Aviation Administration Report No. DOT/FAA/CT-82/42, 1982

Note: This report reviews human exposure data for Halon 1211 and 1301

- Chattaway,A. "The Development of A Hidden Fire Test for Aircraft Hand Extinguisher Applications", Civil Aviation Authority Paper No. 95013, London, 1995.

  Note: This report describes the development of the hidden fire test for hand-held extinguishers.

- CFR Title 40: Protection of the Environment, Part 82-Protection of Stratospheric Ozone, Subpart G-Significant New Alternatives Policy Program and Subpart H-Halon Emissions Reduction
- Cherry, R.G. W. et al, "A benefit Analysis for Enhanced Protection from Fires in Hidden Areas on Transport Aircraft", Federal Aviation Administration Report No. DOT/FAA/AR-02/50, CAA Paper 2002/01.

- Blake, D.R. "Effectiveness of Flight Attendants Attempting to Extinguish Fires in an Accessible Cargo Compartment", Federal Aviation Administration Technical Note DOT/FAA/AR-TN99/29, 1999

10. HOW CAN I OBTAIN FAA PUBLICATIONS

Contact the National Technical Information Service, Springfield, Va 22161

FAA publications can also be found on the following Web Site of the FAA Fire Safety Branch:
http://www.fire.tc.faa.gov/reports/reports.asp

APPENDIX 1, Figure 1 through x

Figure 1. HFC 236fa Selector for Compartments with a known Air Change Time

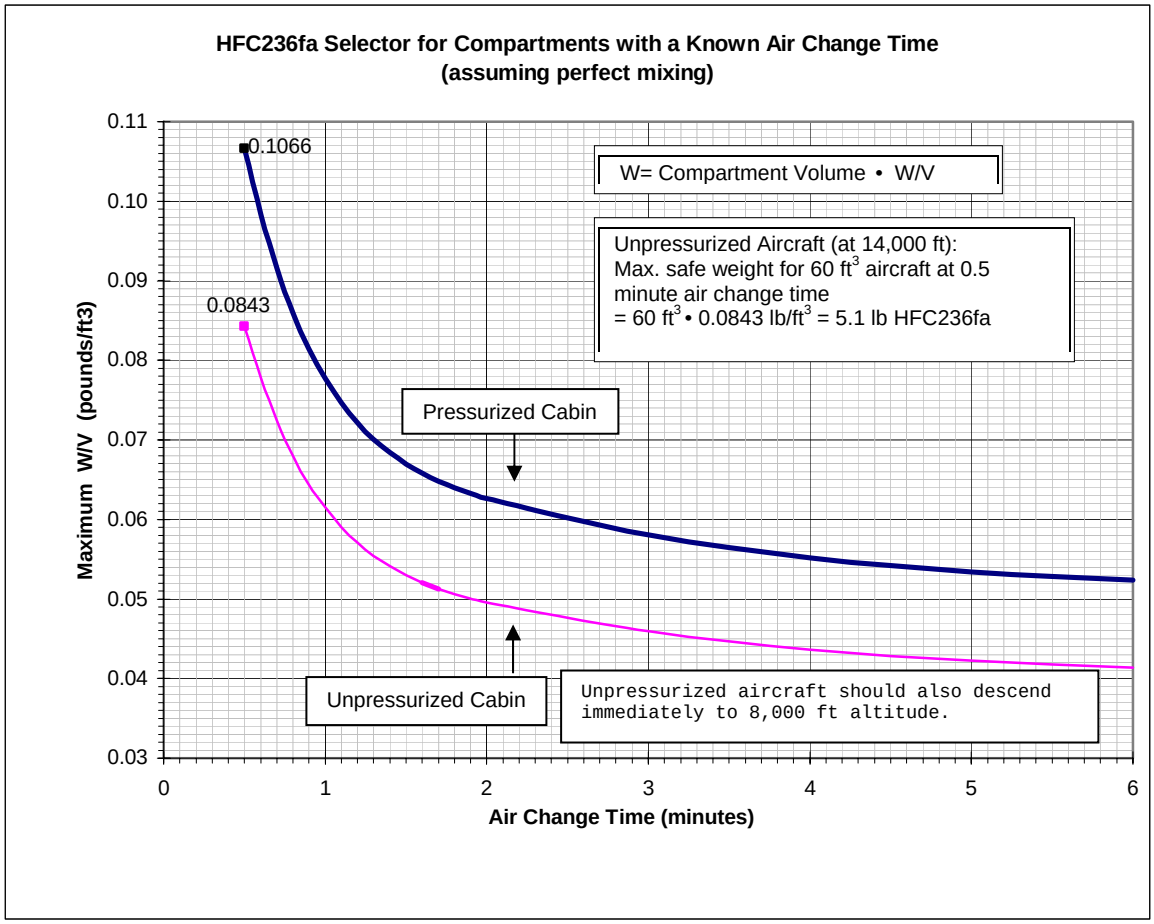
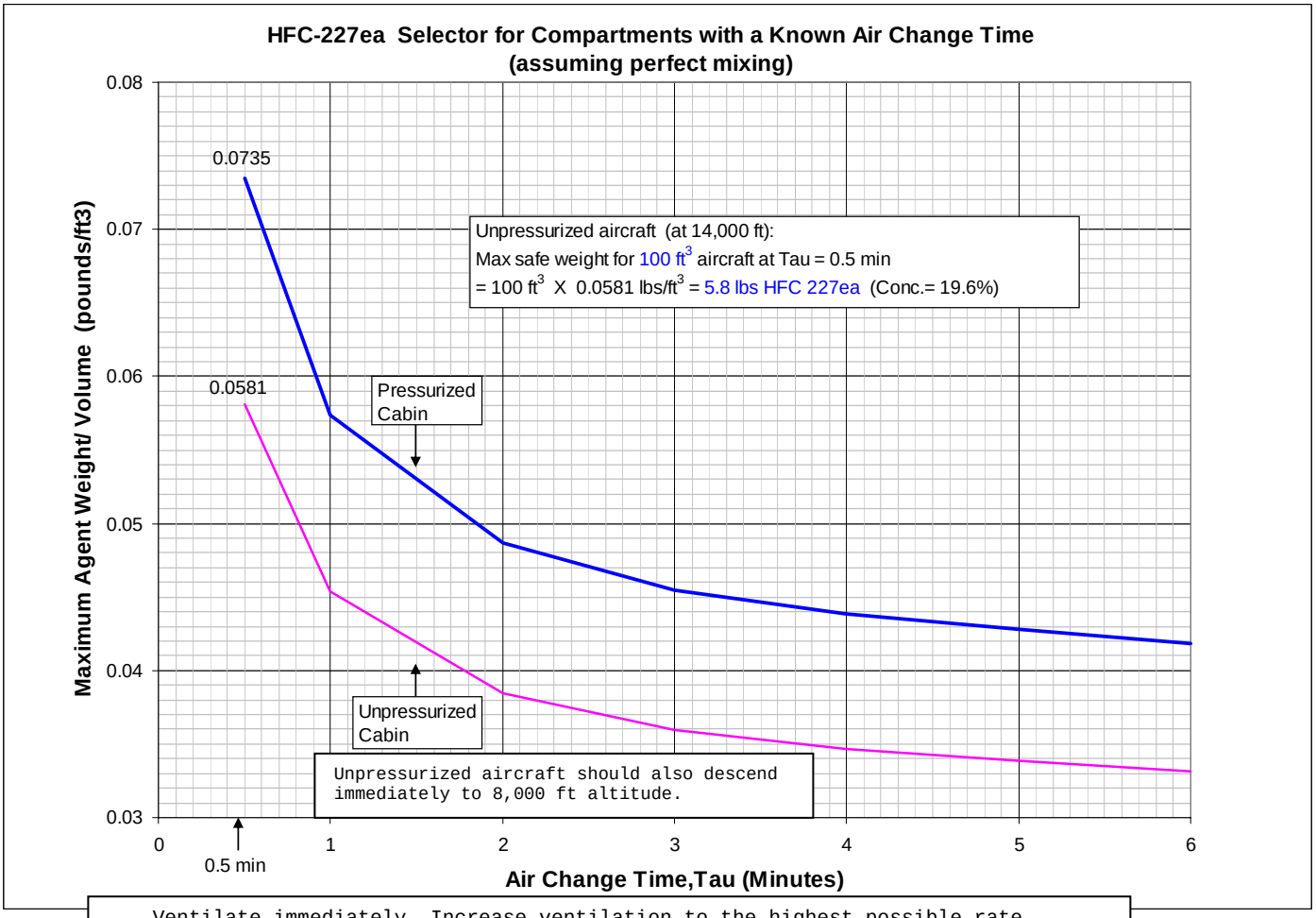


Figure 1. HFC 227ea Selector for Compartments with a known Air Change Time



Ventilate immediately. Increase ventilation to the highest possible rate.

If Air change time is unknown or exceeds 6 minutes, use unventilated data (Prolonged exposure to these agents may be hazardous):

- W/V = 0.0395 pounds/ft^3 for Pressurized Cabins
- W/V = 0.0312 pounds/ft^3 for Nonpressurized Cabins

Unpressurized Aircraft should descend at a minimum rate of 1,000 ft/minute if agent weights are greater than half the maximum safe weight for a given volume to avoid the life threatening hazards of low oxygen hypoxia resulting from the agent displacing oxygen from the air in the compartment. This guidance should be followed regardless of ventilation rate.

Immediate descent to 8,000 feet or lower is recommended for all aircraft to minimize exposure to halogenated agents.

Appendix 2:

Table 1. Throw Ranges for 5B:C Halocacarbon Clean Agent Extinguishers

Agent	Throw Range (Feet)	Notes
HCFC Blend B		
HFC 236fa		
HFC 227ea		
Halon 1211	9-15	Leaves the nozzle in a stream that is about 85% liquid and 15% gas
Halon 1301	limited	Gaseous upon discharge

Apendix 3:

Add Tables of Aircraft Volumes

The information in the table below is from: Hocking, M.B. (1998). *Indoor Air Quality:Recommendations Relevent to Aircraft Passenger Cabins*. American Industrial Hygiene Association Journal. 59:446-454.

Aircraft	Minimum Reported Air Changes Per Hour	Minutes for Air Change	Cabin Volume, m3	Cabin Volume, ft3
Boeing 737-100	26.1	2.30	120	4238
McDonald Douglas DC9-30	27.3	2.20	124	4379
Boeing 737-200	17.7	3.39	131	4626
McDonald Douglas DC9-50	18.8	3.19	148	5227
McDonald Douglass DC10-10	22.8	2.63	149	5262
Boeing 737-300 (42)	14.2	4.23	149	5262
Boeing 727-100	22.9	2.62	151	5333
Boeing 727-200	18.8	3.19	165	5827
McDonald Douglas DC9-80/MD80 (22)	19.7	3.05	173	6109
Boeing 757 (48)	15.6	3.85	276	9747
Boeing 767-200 (52)	10.3	5.83	319	11265
Airbus Industrie 310 (53)	9.7	6.19	334	11795
McDonald Douglas DC10-40 (35)	14.9	4.03	419	14797
Boeing 767-300 (-)	11.1	5.41	428	15115
Lockheed L1011-50	19.3	3.11	494	17445
Lockheed L1011-1/100	17.8	3.37	537	18964
Boeing 747 (26)	14.7	4.08	790	27899
	Avg.	**3.68**		

Volumes for Smaller Commercial Aircraft

Aircraft	Number of Seats	Cabin Volume, ft3
Embraer ERJ-135	37	968

Embraer Brasilia EMB-120	30	968
Saab-340A & 340B	33	1180
Fairchild Dornier 328	32	1183
DASH-8, 100&200 series	37	1328
Saab 2000	50	1860
Embraer ERJ-145	50	1872
CRJ-200	50	2015
CRJ-700	64	2682
DASH-8, 400 series	78	2740

Volumes for Aircraft that normally seat 6 to 8 passengers

Aircraft	Cabin Volume, ft3	
Piper PA31T Cheyenne	151	
Cessna Caravan II	152	
Socata TBM-700	155	estimated by Pilatus
Raytheon Beechcraft King Air 90 & 100	179	79.6 for cockpit
Gulfstream Turbo Commander	184	six seater
Gulfstream Jetprop	184	
Sino Swearingen SJ30-2	190	
Cessna Corsair, Conquest I	193	
Cessna 421	217	
Cessna 414	226	
Rockwell Gulfstream Commander GC-1000	249	
Cessna Caravan 675	254	
Cessna Caravan Amphibian	254	
LearJet 31A	271	
Cessna Citation CJ1	300	
Raytheon Beechcraft King Air 200	303	includes bathroom and internal baggage
Raytheon Beechjet 400	305	95 for cockpit
VisionAire Vantage	310	
Raytheon Premier I	315	
Pilatus PC12	330	
Cessna Grand Caravan	340	
Cessna Citation CJ2	350	
Raytheon Beechcraft King Air 300/350	355	includes bathroom and internal baggage
LearJet 40	363	
Gulfstream G100	367	
LearJet 45/45XR	410	
LearJet 60	453	
Gulfstream G150	465	
Gulfstream G200	868	